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Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss the potential impacts of the growing use of computers and the Internet on electricity consumption.

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Background

We are all well aware of the explosive growth of personal computers (PCs) and the Internet in our homes and in all aspects of our daily lives—schools, businesses, and industries. A recent report from the Department of Commerce, *The Emerging Digital Economy II*, is one of many recent studies undertaken to analyze the growing public access and availability to the Internet and the growth of electronic commerce (E-commerce).[1] These studies have indicated that E-commerce,

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[1]Economics and Statistics Administration, U.S. Department of Commerce, *The Emerging Digital Economy II*, (Washington, DC, June 1999), www.ecommerce.gov/ede.

in the form of business-to-consumer and business-to-business sales over the Internet, may transform the way business is currently carried out, while increasing productivity and reducing waste. Some argue that the increase in the use of electronic equipment will increase energy use while others contend that the Internet will temper future growth in energy use by reducing the need for energy-intensive manufacturing, retail space, and transportation requirements.

Electricity Use – Past and Future

From 1985 to 1995, retail electricity sales grew at a rate of 2.6 percent per year, faster than any other delivered energy source over the same ten year period.[2] Since 1995, the use of the Internet has increased dramatically, yet retail electricity sales have grown by 2.1 percent per year, 0.5 percentage points less than the previous 10 years.[3] Economic activity, weather, and other factors can, of course, affect these growth rates. However, some might conclude that the Internet, in and of itself, has not yet caused a significant impact on the amount of electricity used by households, commercial establishments, and large industrial users combined, due to the substitution away from other uses of electricity, such as color televisions and stereo systems. From 2000 to 2010, the *Annual Energy Outlook 2000* (*AEO2000*) projects electricity sales to grow at about 1.5 percent per year, as trends in energy efficiency, appliance saturation, population, and economic growth act to slow the growth realized in the 1980s and 1990s.[4] An in depth look at how electricity is used in each sector will help in understanding the projected growth rates for electricity in the *AEO2000*.

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[2]Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(99/12),(Washington, DC, November 1999).

[3]Energy Information Administration, *Short Term Energy Outlook*, DOE/EIA-0202(2000/01), (Washington, DC, December 1999), www.eia.doe.gov/emeu/steo/pub/10tab.html.

[4]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000), (Washington, DC, December 1999).

Residential Buildings

Households currently consume more electricity, 35 percent, than any other end-use sector in the United States (Figure 1). The uses for electricity in the house are numerous, with no single service responsible for more than 13 percent of the total electricity sold to the residential sector on an annual basis. Over the past decade, many new electronic devices have made their way into the home, including PCs and peripheral equipment. Although PCs have been on the market for more than 15 years, sales have recently skyrocketed as a result of the development of various software applications and the popularity of the Internet. Trade publications estimate that about half of the households in the United States have at least one PC, up from 35 percent in 1997.[5]

Even with the increasing use of PCs in the residential sector, it is estimated that in 1999, PCs accounted for only 2 percent of the electricity delivered to the home (Figure 1).[6] The four largest uses for electricity—space heating, space cooling, refrigeration, and water heating—account for almost half of all electricity used on an annual basis. In fact, an average household using electricity as its main space heating fuel would use nearly 12 times more electricity for space heating than for PCs.[7] PCs, however, are one of the fastest growing uses for electricity, as more householders purchase them and those that have them use them for more than simply balancing their checkbook. Even with the explosion in the use of a variety of home electronics, residential electricity sales in the 1990s grew at an average rate of only 2.4 percent per year (compared to 2.6 percent per year in the 1980s), about twice the rate of household formation (1.2 percent per year). Within this decade, residential electricity consumption declined from its previous year total twice (1992 and 1997), as cooler summer temperatures, particularly in 1992, significantly reduced

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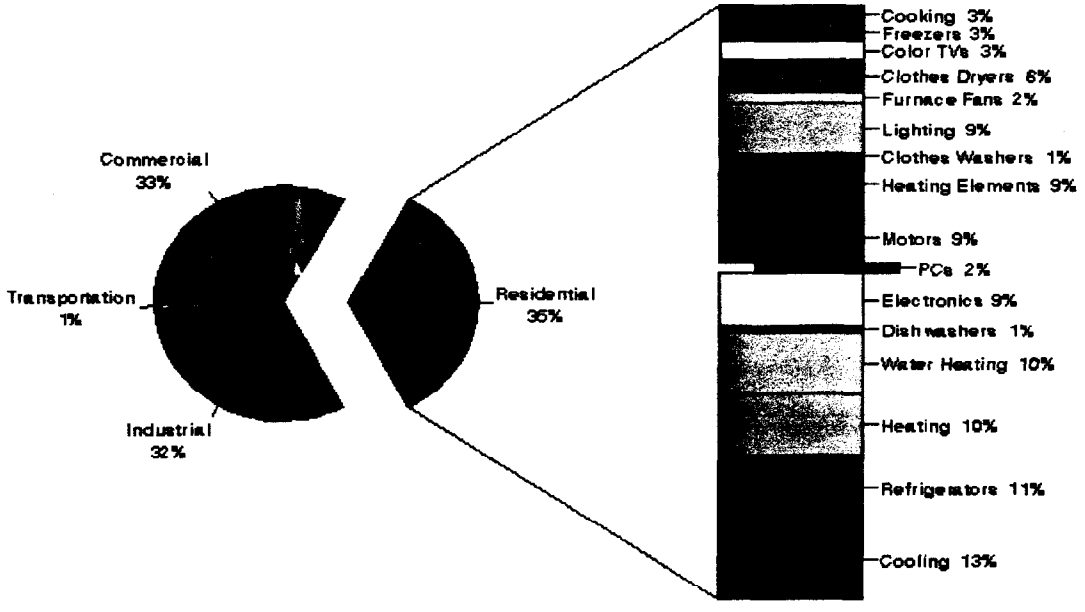
[5]Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, DOE/EIA-0632(97), (Washington, DC, November 1999).

[6]Residential PC use is defined as the electricity required for the central processing unit (CPU) and monitor.

[7]Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, DOE/EIA-0632(97), (Washington, DC, November 1999).

the amount of electricity needed for air conditioning. The *AEO2000* projects residential electricity sales to grow at an annual rate of 1.5 percent per year through 2010, as household formation growth slows and energy efficiency increases, dampening the growth in miscellaneous electric devices. In *AEO2000*, electricity use by miscellaneous electric appliances, including PCs, color televisions, and the like, are projected to grow at 3.2 percent per year through 2010, more than twice the rate of the average electricity growth rate, and more than three times the rate of household formation. These growth rates are based on saturation rates and recent data detailing the use of these appliances in the home.

Figure 1. Residential Sector Site Electricity Consumption by End-Use, 1999



Source: Annual Energy Outlook 2000.
Note: PCs are defined as central processing unit and monitor.

The commercial sector currently uses about one-third of all of the electricity consumed in the United States (Figure 2). PCs[8] and other office equipment were estimated in 1999 to account for 2.4 and 7.5 percent of total commercial electricity use, respectively, for a total of about 10 percent. In contrast, lighting in commercial buildings is estimated to require more than three times the electricity needed to power PCs and other office equipment. Space conditioning—heating, cooling, and ventilation—also commands a significant share of commercial electricity use, about twice that used for PCs and office equipment.[9] Refrigeration, water heating, cooking, and various other services account for the remaining commercial energy use.

EIA's recent report on PC use in commercial buildings[10] estimated that the number of PCs and computer terminals used in commercial buildings increased by 45 percent from 1992 to 1995. For all commercial buildings, there were three PCs or computer terminals for every five employees in 1995, and in office buildings, which comprised nearly half of all computers used in the commercial sector in 1995, there were four PCs or computer terminals for every five employees. However, the dramatic growth in commercial PCs has not translated to similar growth in electricity use, which has averaged 3.0 percent per year in the 1990s (compared to 4.5 percent per year in the 1980s) because PC use still comprises a relatively small share of commercial electricity consumption. Electricity used for all office equipment, PCs, and miscellaneous applications, including Internet-related uses, is projected to grow at 3.0 percent per year through 2010, more than 2.5 times the rate of commercial floor space, and nearly twice the rate of total commercial sector electricity use (Figure 3). The growth rates assumed for these miscellaneous uses are based on recent data on appliance saturation and usage rates.

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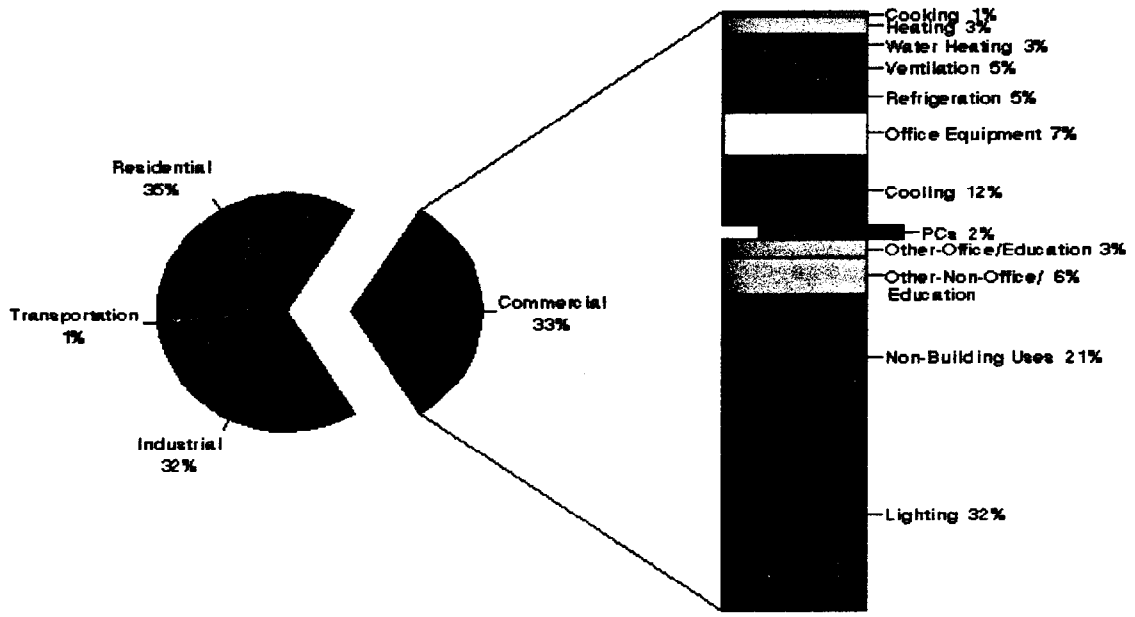
[8]Commercial sector PC use is defined as the electricity required for the central processing unit, monitor, and laser printer.

[9]Office equipment includes FAX machines, copiers, and point of sale equipment (cash registers). Telecommunication equipment and routers for Internet connection are included in "Other - Office/Education" in Figure 2.

[10]Energy Information Administration, *Personal Computers and Computer Terminals in Commercial Buildings*, (Washington, DC, April 1999), www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pcsterminals.html.

Figure 2. Commercial Sector Site Electricity Consumption by End-Use, 1999



Source: Annual Energy Outlook 2000.
Note: PCs are defined as the central processing unit, monitor,and laser printer.

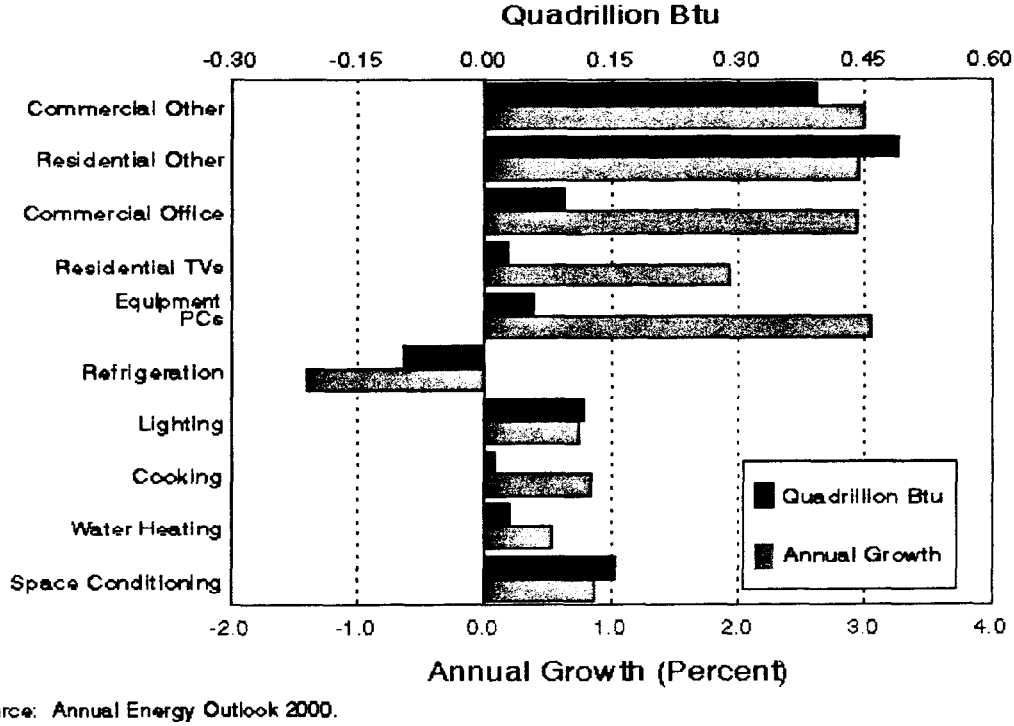
Industrial Manufacturing and Facilities and Economic Growth

The EIA report *Manufacturing Consumption of Energy 1994* [11] estimates that less than 2 percent of all electricity used in manufacturing facilities in 1994 was consumed for facility support. Facility support, in this case, includes the functions normally associated with office or building operations other than facility lighting, heating, ventilation, and air conditioning. Operation of office equipment such as PCs and copying machines are part of facility support. However, cooking and refrigeration in cafeterias, elevator operation, and the energy used by vending

[11]Energy Information Administration, *Manufacturing Consumption of Energy 1994*, DOE/EIA-0512(94), (Washington, DC, December 1997) and ftp://ftp.eia.doe.gov/pub/pdf/consumption/051294.pdf.

machines are a few examples of other functions included in facility support, highlighting the fact that office equipment use comprises just a small fraction of the electricity used in manufacturing facilities.

Figure 3. Buildings Sector Site Electricity Growth by End-Use, 2000-2010



Source: Annual Energy Outlook 2000.

There are limited data detailing the energy use associated with the manufacturing of computer-related products. The Annual Survey of Manufactures (ASM)[12], however, reports the amount of electricity purchased by Standard Industrial Classification (SIC) 357 (computer manufacturing) and SIC 367 (semiconductor manufacturing). In 1994, computer manufacturers purchased 4.9 billion kilowatthours of electricity while semiconductor manufacturers purchased 15.7 billion

[12]Bureau of the Census, U.S. Department of Commerce, *1994 Annual Survey of Manufactures*, M94(AS)-1, (Washington, DC, March 1996).

kilowatthours of electricity, which together account for 2.6 percent of the 802 billion kilowatthours of total manufacturing sector purchased electricity. These two sub-sectors accounted for 5.2 percent of the total value of manufacturing shipments in 1994. In 1996, the ASM reported that these same SIC groups accounted for the same percentage of total manufacturing purchased electricity, while its value of manufacturing shipments increase to 6.2 percent.[13] From 2000 to 2010, *AEO2000* projects the value of output for SIC 367 to grow at 7.3 percent per year, one of the fastest growing manufacturing sectors in the U.S. economy, which contributes to a projected overall Gross Domestic Product (GDP) growth rate of 2.3 percent per year through 2010. Total gross output of the U.S. economy is projected to grow at 2.3 percent per year through 2010, the same rate as GDP. As a percentage of total gross output, SIC 367 is projected to grow to 2.8 percent by 2010, up from 1.7 percent in 2000. The high rate of growth in SIC 367 contributes to an electricity sales growth rate of 3.2 percent per year for metal based durables manufacturing, more than twice the rate of overall industrial sector electricity sales through 2010.

The Digital Age and Energy Consumption

The Digital Age has brought about many new electronic devices over the recent years, many of which are associated with the use of PCs. For household PC use, current electricity use estimates range from 130[14] to 262[15] kilowatthours per year, based on many factors, including hours of use, efficiency features (e.g., sleep mode), and monitor size. While it appears obvious that the Internet has increased the number of hours a home PC might operate, it is not clear that the energy use associated with the extra operating hours necessarily adds extra kilowatthours to the average

[13]Bureau of the Census, U.S. Department of Commerce, *1996 Annual Survey of Manufactures*, M96(AS)-1, (Washington, DC, February 1998).

[14]Ernest Orlando Lawrence Berkeley National Laboratory, *Energy Data Sourcebook for the U.S. Residential Sector*, (Berkeley, CA, September 1997).

[15]Arthur D. Little, *Electricity Consumption by Small End Uses in Residential Buildings*, (Cambridge, MA, August 1998).

monthly electricity bill. In some cases, the time spent on the Internet could supplant watching television or playing video games, both of which consume electricity. In fact, a home theater equipped with a cable box and VCR could, depending on the features of the equipment, use more electricity than surfing the Internet for a comparable amount of time. Newer PCs are equipped with efficiency features that allow the unit to "power down" when left inactive for a certain amount of time. This feature, however, can be disabled in a manner similar to flow restriction devices in showerheads, limiting the overall effectiveness of the option. Current estimates for Internet use at home are 7 hours per week, less than half the hours (15) estimated for television use. Recent trends have shown that hours spent on the Internet have been increasing, while time spent watching television has been flat or falling.[16]

In the commercial sector, growth in the number of PCs is expected to slow in the next decade as the market becomes saturated. As noted earlier, office buildings were estimated to have four PCs for every five employees in 1995. Office workers may increase Internet use; however, this may offset use of other types of office and computer equipment, such as FAX machines and copiers or travel for reference materials. In short, it is extremely difficult to separate computer use associated with the Internet from computer use in general, given the fact that no matter the application, the desktop computer will use the same amount of electricity (i.e., ON is ON).

Uncertainties Relating to Electricity Consumption

The uncertainty related to future electricity demand due to the growth of the Internet is just a small component of all the uncertainty relating to future electricity demand. There are many factors that can either increase or decrease the use of electricity on a per household or per building basis. As a wealth of new electronic devices makes its way into homes and businesses,

[16]EEnergy Informer Newsletter, (Menlo Park, CA, January 2000).

electricity use can be expected to increase. However, many programs exist to reduce the amount of electricity needed to power most major appliances. These include Federal equipment efficiency standards, State and local building codes, research and development (R&D) programs, voluntary programs, and executive orders for Federal agencies. More efficient versions of current technology can provide a means to offset the expected growth in electricity use due to the introduction of new electronic devices. However, the timing and widespread acceptance of these technologies provide a degree of uncertainty regarding their effectiveness. The implementation of unforseen policies and advances in technologies can easily dwarf any impact that the Internet might have on electricity demand. This is especially true internationally, where regions such as China and South America are in the process of providing electricity to hundreds of millions of people. Europe is currently transitioning to a continent-wide wholesale market for electricity, which could have a major impact on future electricity demand, regardless of how fast the Internet grows.

Future energy prices and their effects on consumer behavior add further uncertainty to projections of total energy and electricity consumption. It is possible that the increasingly competitive structure of the electricity generation, transmission, and distribution industry may lead to declining electricity prices. In that case, consumers are likely be less concerned about their use of electricity-consuming services and the purchase of energy-efficient products. As the marginal price of providing a particular service falls, as a result of either declining energy prices or increasing energy efficiency, one would expect the energy intensity for that service to increase. This "rebound" effect is particularly important in space conditioning applications, where a direct response to higher or lower energy prices can be easily accomplished by modifying the thermostat setting. On the other hand, higher prices of fuels used to generate electricity, electricity industry developments, or policy initiatives to reduce U.S. energy consumption and emissions could lead to higher electricity prices.

Electricity Use and the Kyoto Protocol

In the EIA report *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*,[17] reference case electricity sales are projected to grow at 1.5 percent per year from 2000 to 2010, identical to the rate projected in *AEO2000* over the same period. Depending upon the magnitude and availability of flexibility measures to meet the Kyoto Protocol (U.S.carbon emissions 7 percent below their 1990 levels), the carbon price is projected to range from $67 to $348 ($1996) per metric ton in 2010. Average electricity price increases in these scenarios in 2010 range from 20 to 86 percent over the reference case level of 6 cents per kilowatthour. Residential electricity prices in the Kyoto study range from 19 to 82 percent over reference case levels in 2010. Even at the most extreme price increase, it is not expected that household use of the Internet would substantially change. With the near doubling of projected electricity prices by 2010 compared to recent history in the most extreme case of the Kyoto study, operating a home PC for a month would cost about 5 times less than the cost of a standard monthly subscription for Internet access.[18] In the most extreme case of the Kyoto study, residential sector electricity use by PCs was projected to decrease by 14 percent (1.7 billion kilowatthours) relative to the reference case in 2010.

Recent Studies on the Digital Age and Energy Use

Several recent articles have indicated that the increasing popularity of the Internet will dramatically increase electricity use, creating the need for new power plants, while others suggest that the Digital Age will bring about structural change leading to more efficient use of resources and energy.

The Internet Begins With Coal: A Preliminary Exploration of the Impact of the Internet on

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[17]Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03, (Washington, DC, October 1998).

[18]This calculation is based on a PC using 262 kilowatthours per year, electricity prices at 13.9 cents per kilowatthour, and Internet access costing $15 per month.

Electricity Consumption by the Greening Earth Society, and the derivative *Dig more coal – the PCs are coming* in the May 31, 1999, issue of Forbes Magazine, both contend that the Internet economy will require a substantial increase in electricity use to keep up with the pace of Internet development. In summary, these articles suggest that there are over 200 million computers in homes and businesses, and that these computers, coupled with their accessories and associated devices, use about 8 percent of the U.S. demand for electricity. In addition, these articles suggest that within 10 years, half of the electric grid will power the Internet and E-commerce activity. The Forbes article, as the title suggests, purports that coal will be the generating fuel of choice to meet the demand for electricity.

The *AEO2000* reference case projects electricity sales to grow at 1.5 percent per year through 2010, half the rate implied by the Forbes article. This projection includes recent trends in the growth of consumer electronics, recently enacted Federal appliance efficiency standards, the effects of structural changes in the economy, and electricity deregulation. These factors have different effects on the electricity growth rates and consumption of various building sector end uses (Figure 3). However, at the average rate of growth of 1.5 percent per year, electricity generated by coal increases by only 13 percent (242 billion kilowatthours), while electricity generated by natural gas increases by 96 percent (309 billion kilowatthours). By 2010, only 2 percent of cumulative electric generator additions are projected to be coal-fired, while 94 percent are projected to be natural gas-fired.

If the demand for electricity were to grow at 3 percent per year through 2010, as suggested in the Forbes article, generation from coal would account for 32 percent of the increase, while natural gas would account for 60 percent.[19] In this "high electricity growth case," coal would account for less than 50 percent of electricity generation, while generation from natural gas would nearly

[19]Energy Information Administration, National Energy Modeling System run HIEL3.D122999A.

triple, increasing to 25 percent by 2010. Given the increased reliance on natural gas in the electric generation sector, the 16 percent increase in electricity sales in this "high electricity growth case" would increase carbon dioxide emissions by 6.6 percent in 2010 (117 million metric tons of carbon equivalent), relative to the *AEO2000* reference case forecast.

While it is indisputable that the Internet and E-commerce are growing rapidly, estimates regarding the electricity associated with its direct use cited in the Forbes article have been subject to some debate. Lawrence Berkeley National Laboratory, for example, asserts that electricity use associated with the Internet has been overestimated by a factor of 8 in the Forbes article.[20] The Forbes article appears to have severely over estimated the number of PCs in use today. While it is true that sales of PCs have been brisk of late, not all of these purchases are additive to the stock. In fact, because of fast stock turn over (roughly 2 to 3 years), many computer purchases replace older units, especially since the technology has been evolving so rapidly over the past several years. Also, for many of the devices associated with Internet use and dot-com companies, such as routers and mainframe computers, the electricity use was estimated using the rated power, which is typically twice the actual power draw.[21] Correcting for this error reduces the amount of electricity attributable to routers in the Forbes analysis by a factor of three. With all of these corrections taken into account, it is unlikely that the Internet will require 30 to 50 percent of the electric grid in the coming years, as suggested in the Forbes article.

While the *AEO2000* forecast does include Internet use in the projections, it does not include it as a separate category due to the difficulties in quantifying its exact use. Figures 1 and 2 detail electricity use in the residential and commercial sectors for 1999. Electricity use attributed to PCs accounted for about 2 percent (19 and 27 billion kilowatthours in the residential and commercial

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[20]Lawrence Berkeley National Laboratory, Memorandum LBNL-44698, (Berkeley, CA, December 1999).

[21]Lawrence Berkeley National Laboratory, Memorandum LBNL-44698, (Berkeley, CA, December 1999).

sectors, respectively) of the electricity used in each sector, with peripheral equipment related to the Internet in businesses and home PCs accounting for 1.5 and 0.3 percent (16 and 3 billion kilowatthours) of commercial and residential sector electricity use, respectively. With the addition of the electricity used to manufacture computer-related equipment, electricity used by all computers and Internet-related uses accounted for less than 3 percent (98 billion kilowatthours) of all domestic electricity sales in 1999, well below the 8 percent (263 billion kilowatthours) reported in the Forbes article. Included in the *AEO2000* forecast are the recent historical growth trends in miscellaneous uses of electricity, of which the Internet is one, in order to quantify future electricity use. Even with the inclusion of these recent growth rates, the amount of electricity used by PCs and peripherals in the home and PCs and office equipment in commercial establishments is well below the amount claimed in the Forbes article.

A recent article by The Global Environment and Technology Foundation (GETF) entitled *The Internet Economy and Global Warming* takes the position that the growth in the Internet will help companies become more energy and resource efficient, contributing to higher economic growth and less negative impact on the environment. These claims are based largely on economic and energy data for two years, 1997 and 1998, which exhibited fairly substantial increases in economic growth while energy consumption "hardly grew at all."[22] The paper suggests that the precipitous drop in energy intensity over this time period can be attributed to structural changes in the economy and gains in energy efficiency. While it is true that total delivered energy (excluding fuel used to generate electricity) decreased from 1996 to 1998, it should be noted that the decline is almost entirely due to a decrease in the use of natural gas in the buildings and industrial sectors.[23] Natural gas use in these sectors decreased by 6 percent over this period, however, three-fourths of the decrease was in the buildings sector, where gas-weighted heating degree-days

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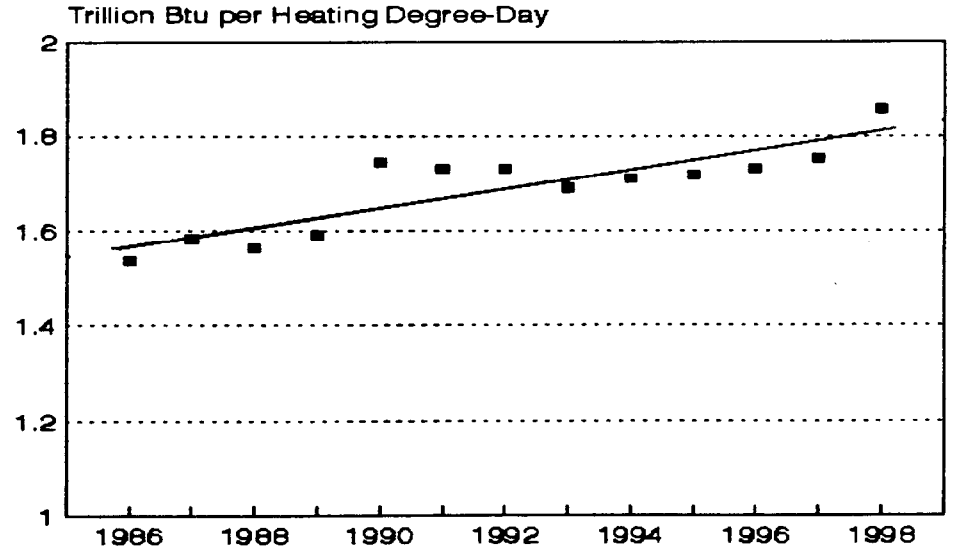
[22]The Center for Energy and Climate Solutions, *The Internet Economy and Global Warming*, December, 1999.

[23]Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(99/12),(Washington, DC, November 1999).

were 16 percent lower in 1998 than were observed in 1996. In fact, through the first nine months of 1999, natural gas consumption in the buildings sector was 4.1 percent higher than the first nine months of 1998, as winter temperatures became more "normal" in early 1999. In fact, buildings sector natural gas consumption, when normalized for weather fluctuations, increased in 1998, relative to all other years since 1986 (Figure 4). Although customer growth is not reflected in Figure 4, the trend line shows that growth in natural gas use, in terms of customers and/or intensity, has more than offset increases in efficiency. If energy efficiency was responsible for the decline in natural gas consumption over this period, one would not expect such a marked increase in this index in 1998, relative to 1996. Overall, one would expect the change in energy consumption and intensity to have occurred over a widerrange of fuels and sectors if energy efficiency and structural changes were responsible for the lower energy use over this two year period, which was not the case.

Figure 4. Buildings Sector Natural Gas Consumption per Heating Degree-Day, 1986-1998



Sources: Monthly Energy Review, December 1999 and Short Term Energy Outlook, January 2000.

The GETF paper discusses various energy saving consequences brought on by widespread adoption of the Internet, particularly those related to E-commerce. The merits of E-commerce

are numerous. The Internet has been successful in bringing together buyers and sellers of goods, on a virtually international level, reducing transactions costs in the process. Ford and General Motors, for example, have plans to integrate their respective supply chains via the Internet, allowing for a more precise inventory scheme and allowing vendors to compete in an auction-type setting for the right to supply parts. These new concepts may radically change the way companies compete for business, but the effect on energy consumption is vague at best. To the extent that this new business model lessens the need for energy-using services such as business travel, retail outlets, or the production of excessive inventories, overall energy use may decline. On the other hand, as electricity markets are deregulated and electricity is auctioned via the Internet, electricity prices might decline, effectively making some investment decisions regarding energy efficiency less attractive. However, real-time pricing in wholesale electricity markets has been subject to large price spikes over the past several years. A more coordinated market structure via the Internet may help alleviate some of these spikes in the future, as buyers and sellers of electricity are brought together more efficiently in the marketplace. Other energy-saving applications of the Internet could include more efficient monitoring of heating and cooling equipment in buildings and increased telecommuting, which could reduce transportation energy use.

Summary and Conclusions

At this point in time, it is too soon to come to any conclusions as to the precise energy path of electricity use resulting from Internet and Internet-based commerce. Attempts have been made to show that the growth of the Internet will substantially increase electricity use, while others have stated that the growth in the Internet and the information technology sector will decrease energy use. There are many problems associated with trying to estimate the direct impact that the Internet will have on energy consumption. As mentioned earlier, Internet use is not purely additive as implied in the Forbes article. Other uses for electricity, such as television and stereo equipment, will most likely see less use in the home as Internet use rises. The energy implications, therefore, are vague at best, especially given the lack of time series data available to assess the

likely impacts. The *AEO2000* reference case includes the major policies and market phenomena that have and are projected to continue to influence the amount and type of energy used throughout the U.S. economy. Recent trends in the growth of electronic equipment, stock turnover, appliance efficiency standards, structural changes in industry, electricity restructuring, and macroeconomic activity all factor into the development of the *AEO2000* reference case forecast. While there is uncertainty in all of these elements, it is clear that the size of Internet electricity use today is small compared to that of all of the other uses of electricity. The uncertainties relative to all those uses, including the Internet, could result in higher or lower electricity forecasts than those of *AEO2000*.